# Chapter F-6
# Procedures for Undisturbed Soil Sampling In Borings

## 6-1. Advancing the Borehole

Position the drill rig over the sampling location, chock the wheels on the drill rig, and adjust the mast to a vertical position. Place the drill rods and related equipment at a convenient location for use with respect to the drill rig. The drill rods, sampling equipment, casing, etc., may be placed about 5 m (15 ft) from the drill rig. Set the fluid slush pit, if used, at the drill rig. The inspector's work station, areas for sample storage, power units, support vehicles, and other equipment can be located at greater distances, depending on the type of drilling and/or sampling operations, site topography, weather conditions, logistics, etc.

After a vertical pilot hole has been established, attach the drill bit or auger to the drill rod and lower the string into the borehole. Attach more drilling rods or auger flights, as necessary. At the bottom of the borehole, the depth of the borehole is advanced to the desired depth by rotating the auger or bit and applying a downward pressure from the drill rig or by gravity feed as required to achieve a satisfactory penetration rate. After the hole has been advanced to the desired sampling depth, remove the excess cuttings from the bottom of the hole before the drill string is withdrawn. As the string is withdrawn, disconnect the sections of rod and lay aside. Repeat until the cutting head is retrieved.

When lowering the equipment into the borehole to a new sampling depth, repeat the above procedures in reverse order. Count the number of rods to determine the depth of the borehole. Carefully monitor and record the depth of the hole for use during the sampling operations. All trips up and down the borehole with the drill string should be made without rotation.

In order to obtain an undisturbed soil sample, a clean, open borehole of sufficient diameter must be drilled to the desired sample depth. The sample should be taken as soon as possible after advancing the hole to minimize swelling and/or plastic deformation of the soil to be sampled.

*a. Diameter of the borehole*. The diameter of the borehole should be as small as practical. If casing is not used, a borehole 6 to 19 mm (1/4 to 3/4 in.) greater in diameter than the outside diameter of the sampler should be sufficient. In soils containing irregular hard and soft pockets that cause deviation of the drill bit or in soils that tend to squeeze, a slightly larger clearance, i.e., 12 to 19 mm (1/2 to 3/4 in.), may be required. When casing is used, the hole should be drilled 6 to 25 mm (1/4 to 1 in.) larger than the OD of the casing. Paragraph 6-2*b* outlines the procedure for setting casing.

*b. Methods of advance*. Boreholes for undisturbed samples may be advanced by rotary drilling methods or with augers. Augers are discussed in Chapters 3, 7, and 8. If rotary drilling is used, the bit must deflect the drilling fluid away from the bottom of the hole. Displacement and percussion methods for advancing boreholes are not acceptable for undisturbed sampling operations.

(1) *Augering*. Auger borings are generally used in soils where the borehole will remain open, usually above the groundwater table. Augers operate best in somewhat loose, moderately cohesive, moist soils. Augers may also be used in medium-to-hard clays, silts, and/or sands containing sufficient fines to prevent the hole from caving. In general, the holes are bored without the addition of water, although the introduction of a small amount of water may aid in drilling in hard, dry, or cohesionless soils. Below the

groundwater table, drilling fluid or casing may be required to stabilize the borehole. Because auger borings typically do not use drilling fluid, the auger boring method may be preferred for drilling in embankment dams, thus eliminating the potential for hydraulic fracturing, and in water sensitive formations.

To advance the borehole using solid- or hollow-stem, single- or continuous-flight helical augers, the auger is attached to the spindle or kelly on a drill. The auger is lowered into the borehole, and downward pressure is applied as the auger is rotated. Sufficient pressure should be applied to cause the auger to penetrate as it cuts. However, the auger should not be forced into the soil so rapidly as to displace the soil outward or downward. A rotational velocity of 50 to 150 revolutions per minute (rpm) is suggested, although the velocity should be adjusted according to the field conditions and the judgment of the driller. In general, a slower rate of feed will result in smaller cuttings, whereas a rotational velocity greater than approximately 150 rpm will result in excessive vibration of the drill string. At a depth of about three- to four-hole diameters above the top of the intended sample, additional care should be taken to prevent disturbance by decreasing the rate of hole advance. At the desired sampling depth, rotate the auger until the cuttings are removed from the bottom of the borehole.

(a) *Short-flight augers.* The short-flight helical auger is particularly advantageous for advancing shallow holes, i.e., the bottom of the hole may be reached with the auger attached directly to the kelly. The depth of the borehole is usually limited to the length of the kelly, which is typically 3 to 6 m (10 to 20 ft). To operate, the auger is lowered to the bottom of the hole and rotated to cut and fill. When the auger flight(s) is filled, the auger is raised above the ground surface without stopping the rotation. After the auger is clear of the borehole, the kelly can be rotated rapidly to throw the soil from the auger. The centrifugal force of the auger rotation causes all but sticky soils to be thrown from the auger; a temporary increase in rotational speed may be required to spin off these soils. Repeated passes must be made in and out of the hole to advance the borehole.

Several trial runs with the auger will determine the amount of advance of the borehole required to just fill the auger. Excess penetration disturbs the soil at the bottom of the hole, whereas an overfilled auger acts as a piston. As the overfilled auger is withdrawn, the sidewalls and the bottom of the hole tend to be pulled inward and upward by suction. This disruption may cause the walls of the hole to squeeze or collapse and to disturb the soil at the bottom of the borehole.

(b) *Continuous-flight augers.* Continuous-flight augers may be used to advance the borehole in all soils except loose sands and gravels. As the auger penetrates the formation, the flights act as a screw conveyor to bring the soil to the surface. Additional sections can be attached to the cutter head to drill to increased depths. Hollow-stem augers may be used as casing to prevent the caving of certain soils; removal of the center rod and pilot bit allows a sampler to be operated through the stem of the auger.

If a solid-stem auger is used to advance the borehole, the auger flights must be removed from the borehole prior to sampling. Pull the drill rods and auger flights from the borehole without rotation. Disconnect the drill rods and auger flights and lay aside. Repeat until the last section of rods or auger flights has been brought to the surface. After the sample has been obtained, lower the auger and drill rods into the borehole using the above procedures in reverse order. Advance the borehole to the next sampling depth. Prior to sampling at the new depth, clean the borehole by rotating the auger until the cuttings are picked up by the auger (cuttings are no longer thrown from the auger flights).

(2) *Rotary drilling.* To advance a borehole using rotary drilling methods, a baffled drag-type or fishtail bit is rotated and advanced by gravity feed and/or downward pressure applied from the drill rig as

required to achieve a satisfactory penetration rate. A suitable drilling fluid, such as compressed air or a water-based bentonite mud, is pumped through the drill rods to clean and cool the bit and transport the cuttings to the surface. The bit rotation speed and the rate of advance as well as the drilling fluid consistency and circulation rate must all be adjusted to produce cuttings small enough to be transported to the surface as fast as the bit penetrates. A drilling mud consisting of a ratio of approximately 22.7 kg (50 lb) of bentonite per 375 $dm^3$ (100 gal) of water performs satisfactorily as a drilling fluid for most conditions and usually eliminates the need for casing. Compressed air may be preferred, however, when sampling dry or water-sensitive soils, such as expansive clays or shales and soils containing gypsum. Rotary drilling equipment is discussed in Chapter 3; drilling fluids are discussed in Chapter 4.

Bottom discharge rotary bits are not acceptable for advancing the borehole for undisturbed sampling. Side discharge bits may be used with caution. Prior to sampling, the loose material from the hole must be removed as carefully as possible to avoid disturbing the material to be sampled. Jetting through an open-tube sampler to clean out the borehole to sampling depth is not permitted.

(3) *Hydraulic-piston sampler*. Advancing boreholes with an hydraulic-piston sampler requires special adaptation. The method is similar to conventional rotary drilling, except the soil is cut away by cutting teeth welded to the bottom of the sampler rather than using a drag-type or fishtail bit to advance the hole. Drilling-fluid ports are provided in the thin-walled sampling-tube head to allow fluid to pass between the sample tube and the main sampler barrel. The rate of drilling fluid circulation should be minimized to prevent jetting ahead of the bit, but sufficient to avoid blockage of the hole. After the boring has been advanced to the sampling depth, a check ball is dropped through the drill rods to close the ports and facilitate a sample push.

(4) *Displacement methods*. Displacement plugs or samplers should not be used to advance boreholes for undisturbed samples. Displacement causes disturbance below the depth of penetration to a depth in excess of three to four times the diameter of the plug or sampler.

(5) *Percussion drilling*. Percussion drilling should not be used to advance boreholes for undisturbed samples. Vibrations caused by percussion drilling creates disturbance to a depth of several borehole diameters.

## 6-2. Stabilizing the Borehole

Boreholes in soft or loose soils, or when the boring is extended below the groundwater level, may be stabilized with drilling mud and/or casing. Generally, drilling mud will stabilize the borehole. However, when severe cases of caving soils are encountered, casing may be required. If casing is used, it should never be driven. If it is advanced ahead of the borehole, heaving at the bottom of the hole could occur. For some soils, it is often very difficult to advance the borehole ahead of the casing because of heaving at the bottom of the hole and squeezing of the sidewalls. For these types of soils, water or drilling mud may help stabilize the hole.

*a. Drilling mud*. Drilling mud is normally used as the drilling fluid for most soils as it efficiently removes the cuttings from the borehole. Drilling mud is also an effective means for minimizing stress relief at the bottom of the borehole, supporting the sidewalls of the hole to prevent caving, and holding the sample in the sampler as it is withdrawn from the boring. Information regarding the use of drilling mud to stabilize the borehole is presented in Chapter 4.

*b.* *Casing*. Casing is normally used to stabilize boreholes only when a particular stratum or caving zone is encountered and must be sealed or when drilling mud would have an adverse effect on the soil to be sampled, such as a dry or water-sensitive formation. Flush-joint or flush-coupled casing is the most satisfactory type of casing. The flush internal surface of this type of casing prevents hanging and jarring of the sampler. Similarly, the flush external surface of the casing minimizes the annular space required between the casing and the walls of borehole and thus ensures a more stable hole. The flush external surface also reduces the resistance for installation and removal of the casing from the hole. When sloughing or crumbly surface material is encountered, a short section of casing may be required, especially when operations extend for several days. Additional information on casing is presented in paragraphs 3-4*d* and 8-1*b*.

When casing is used, the hole should be drilled or reamed to a diameter 6 to 25 mm (1/4 to 1 in.) larger than the OD of the casing to within a few feet of the stratum to be sampled. The casing should then be inserted in the borehole and pushed or jacked to a depth to effect a seal in the soil at the bottom of the casing. The casing should not be pushed into the stratum to be sampled as disturbance could result. Likewise, the casing should not be driven, as many soils are sensitive to the vibrations caused by driving. As a reminder, each joint should be securely tightened as the casing is assembled. Securely tightened joints help to ensure that threads will not be damaged as the casing is advanced. Furthermore, a joint that is securely tightened prior to placement is also much easier to disassemble as it is removed.

After the casing has been seated at the desired depth, the hole must be cleaned before the undisturbed sample can be taken. A noncoring bit such as a drag bit should be used. After the drill string has been lowered into the borehole and circulation of the drilling fluid has begun, the drill string and bit should be rotated and fed downward with a moderate pressure.

As the depth of the hole is increased, the casing may be advanced by rotation and/or jacking to a depth just above the top of the next undisturbed sample. If the casing is advanced by rotation, a casing shoe with teeth set outward may be required to cut a hole with sufficient clearance to advance the casing.

## 6-3. Cleaning the Hole Before Sampling

A clean open borehole with a minimum of disturbed material at the bottom is essential to obtaining satisfactory undisturbed soil samples. A careful, experienced operator can detect excess material in the bottom of the hole by the actions of the tools and should repeat and/or continue the cleaning operations until the hole is clean. After the borehole has been thoroughly cleaned, the depth to the bottom of the hole should be obtained and recorded. This measurement can be compared to the depth of the hole when the sampler or other device is lowered; if discrepancies exist, cuttings suspended in the drilling fluid or slough from the wall of the borehole may have settled to the bottom of the hole.

*a.* *Cleaning with augers*. In boreholes advanced with an auger, the auger is used to clean the hole. After the hole has been advanced to the desired sampling depth and the cuttings have been removed from the auger, the auger should again be lowered to the bottom of the hole and turned several revolutions without advancing the hole to pick up any loose material. The auger must then be carefully withdrawn without rotation to prevent any loss of material from the auger flights or dislodging of material from the sidewalls of the hole.

*b.* *Cleaning with rotary drilling methods*. In boreholes advanced by rotary drilling methods, the bit rotation and drilling fluid pumping rate should be reduced as the bit reaches a depth to within 0.3 m (1 ft) of the desired sampling depth. The bit should then be advanced slowly to the desired depth of the top of the undisturbed sample. Circulation of the drilling fluid should be continued at the reduced pumping rate until the cuttings in the drilling fluid near the bottom of the boring are washed out. The boring is properly cleaned when the concentration of fine particles per unit volume of suspension becomes constant.

## 6-4. Sampling Procedures

Procedures for obtaining undisturbed samples using open- and piston-type thin-walled push-tube samplers and core barrel samplers are discussed in the following paragraphs. Details of the equipment are presented in Chapter 5.

*a.* *Push samplers*. After the borehole has been advanced and cleaned, the assembled sampler is lowered to the bottom of the borehole. Care must be used to prevent dislodging of materials from the sidewalls of the borehole. With the bottom of the sampler just in contact with the soil to be sampled, the drill rods are chucked in the drill rig. This prevents the weight of the drill rods and sampler from bearing upon and possibly disturbing the material to be sampled. To sample, a thin-walled cylindrical tube is forced into the undisturbed soil in one continuous push without rotation.

Thin-walled sampling tubes may be used in very soft to stiff clays, silts, and sands that do not contain appreciable amounts of gravel. Most samplers are about 60 to 75 cm (24 to 30 in.) long, although the length of the sampling drive is limited by the capability of the drilling rig for a continuous smooth push, the type of sampler which is used, and the material to be sampled. Generally, 125-mm- (5-in.-) diam sampling tubes should be used in clays and silts which can be removed from the tube and preserved in an undisturbed state in a wax-coated cardboard tube. Samples of very soft clays and silts which will not support their own weight and cannot be extruded in an undisturbed state should be taken with either 75- or 125-mm- (3- or 5-in.-) diam sample tubes and sealed in the tube with expanding packers or wax. A 75-mm- (3-in.-) diam sample of clean sand is usually satisfactory. High penetration resistances may preclude pushing larger sampling tubes in cohesionless soils, especially in dense sands.

(1) *Methods of advance*. The methods for advancing thin-walled samplers include drill-rig drive, hydraulic-piston sampling, and pushing by hand. These methods and their limitations are discussed in the following paragraphs.

(a) *Drill-rig drive*. One technique of pushing a thin-walled sampler is using the hydraulic drive mechanism on the drill rig. The sampling tube is advanced in one uniform, continuous push without rotation by applying a downward force through the drill rods. If the push is interrupted, it should not be resumed for any reason as adhesion and friction quickly develop between the sample and sampling tube during the interruption. Restarting the push will result in increased penetration resistance and additional disturbance to the sample. Prior to the sampling drive, the rig should be firmly anchored to prevent the reaction of the drive from raising the rig during the push. Screw-type earth anchors (Figure 6-1) are typically installed to a depth of about 1-1/2 m (5 ft). Screw-type earth anchors can be fastened to the drill rig with load binders, as shown in Figure 6-2, to provide adequate anchorage to the rig.

(b) *Hydraulic-piston sampling*. The hydraulically actuated piston sampler uses a variation of the drill-rig drive method of advance which was discussed in the preceding paragraph. The drill rods are chucked and hydraulic pressure is applied downhole through the drill rods to the sampler head. An increase of pressure in the sampler head causes the thin-walled tube to be advanced into the undisturbed soil at the bottom of the hole. The rods and drill rig provide the reaction force for advancing the sampling tube. The hydraulic-piston sampling method of advance cannot be used satisfactorily in hard clays and silts, dense sands, or gravelly soils, as the penetration resistance may cause the rods to buckle. If the drill rods buckle, the sample may be seriously disturbed.

(c) *Pushing by hand*. Usually, an undisturbed sampler is pushed by hand only in test pit sampling where short, small-diameter, thin-walled samplers are used. The sample quality may be enhanced by the advance trimming and pushing technique and the use of tripod frame for guiding the sampling tube. See Chapter 11 for details.

(d) *Mechanical or hydraulic jacking*. Hand-operated mechanical or hydraulic jacks used in field operations produce an erratic, slow rate of penetration and cause vibrations in the drill rod string. As a result, the jacking method should be avoided because of the disturbance to the sample.

(2) *Rate of penetration*. The rate of penetration of a thin-walled undisturbed sampler greatly affects the degree of disturbance to the sample. A fast, continuous penetration of the sampling tube is required to prevent the buildup of friction between the sampling tube and the soil. The rate of penetration should be as constant as possible throughout the drive. Penetration rates on the order of 5 to 30 cm/sec (2 to 12 in./sec) are recommended.

(3) *Sampler withdrawal*. After the sampling drive has been completed, the withdrawal of the sampler should be delayed briefly to increase adhesion and/or friction between the soil and the sampling tube which will assist in holding the sample in the tube. Usually, the time which is required to measure the length of the push and other minor operations following the push is sufficient. The sampler should be withdrawn slowly and uniformly with a minimum of shock and vibration. A fast withdrawal tends to create a vacuum below the sampling tube which may cause a loss of the sample. If drilling fluid is used in the borehole, fluid should be added as the sampler is removed to keep the borehole full all times.

(4) *Open-tube samplers*. Open-tube samplers are perhaps the simplest tool to obtain samples. However, because of the simplicity of the design and operation of the sampler, a lower quality of sample frequently results. A discussion of the procedures for obtaining undisturbed samples with the open-tube thin-walled sampling tube follows.

After the sampler head has been inspected to make sure that the ball check valve is clean, free moving, and functioning properly, attach a sampling tube to the sampler head. One end of the tube should be sharpened to form a cutting edge and should have an inside clearance ratio suitable for the soil being sampled (see paragraph 2-3). Lower the sampler and the drill rod assembly to the bottom of a clean borehole and clamp in the jaws of the chuck on the drill rig. The depth to the bottom of the hole should be recorded.

Establish a reference point and mark the desired length of push on the drill rod. The length of the push should be a few centimeters shorter than the length of the sampling tube to ensure that the sample is not compressed in the tube. When advancing the sampler, note the maximum hydraulic feed pressure or any variation in pressure which would indicate soft, firm, or gravelly zones. After the sampler has been advanced the desired length of drive, rotate the sampler at least two revolutions to shear the soil at the bottom of the tube. Withdraw the sampler from the borehole as carefully as possible to minimize disturbance of the sample.

After the sampler has been removed from the borehole, remove the sampling tube from the sampler head and measure the recovered length of sample. Compare the recovered sample length to the length of the push. Record these data.

Trim about 5 cm (2 in.) of material from the bottom of the sample. Place the trimmings in a jar for use as a water content specimen and for visual classification. Measure the distance from the bottom of the push tube to the bottom of the trimmed sample. Record these data. Insert an expandable packer in the bottom end of the push tube if the sample is to be shipped to the laboratory. If the material is to be extruded on site, the installation of the packers is omitted.

Trim all loose, disturbed material from the top end of the tube. If possible, trim an additional 5 cm (2 in.) into the undisturbed sample; these trimmings can be used to determine the water content and to conduct a visual classification of the material, as suggested in the preceding subparagraph. Measure and record the distance from the top of the tube to the top of the trimmed sample. Insert an expandable packer in the top end of the tube unless the sample is to be extruded on site. Determine the trimmed sample length by summing the lengths to the top and the bottom of the trimmed sample; subtract this sum from the total length of the tube. Record the data.

The trimmings from the bottom (and top) of the sampling tube should be sealed in a glass jar(s) for retention and use at the soils laboratory. The jars should be sealed immediately to keep the soil from drying. Care should be exercised to prevent the soil from becoming contaminated with drilling fluid or other contaminants which could affect the in situ water content or soil classification. A few grams of soil from the trimmings may be used to visually classify the soil according to the procedures listed in Appendix E. A visual description and classification of the soil should be entered in the boring logs (see Chapter 13).

(5) *Piston samplers*. Piston samplers, such as the Hvorslev and the Osterberg samplers, are used for obtaining soil samples above or below the groundwater table, including cohesionless sands and soft, wet soils that cannot be sampled using the thin-walled open-tube sampler. The principal functions of the piston include preventing cuttings, shavings, or slough material from entering the tube as it is lowered to the bottom of the borehole and increasing sample recovery. A discussion of the procedures for sampling with fixed-piston samplers is presented in the following paragraphs.

(a) *Hvorslev fixed-piston sampler*. The Hvorslev fixed-piston sampler is a mechanically activated sampler which contains many precision parts and screw connections. The specific assembly and operation procedures must be performed in the proper sequence to ensure proper operation of the sampler. Before attempting to use this apparatus, the operator should thoroughly understand the mechanics of the sampler because the precision parts could be easily damaged by misuse or incorrect assembly. Consequently, it is suggested that this sampler be used only by or under the direction of an experienced operator.

To operate, the sampler should be assembled with the piston locked flush with the bottom of the sampling tube. Attach drill rods and piston rod extensions, as necessary, and lower the sampler to the bottom of a clean hole. When the sampler is in contact with the bottom of the hole, clamp the drill rods in the drill-rig chuck assembly. It should be noted that the Hvorslev sampler is not prone to cutting into the side of the hole as it is lowered because the piston is locked at the bottom of the sampling tube. Furthermore, the sampler can be placed firmly against the bottom of the hole without picking up cuttings because the piston is locked in position. However, care is required to ensure that the weight of the drill string does not cause the sampler to penetrate or compress the undisturbed soil at the bottom of the hole.

An alternative method of operating the sampler consists of attaching drill rods only, prior to lowering the device to the bottom of the borehole. When the sampler has been placed on the bottom of the hole, lower the piston rods through the drill rods and attach the rods to the top of the sampler. The coarse female thread end on the piston rod should be placed downhole first. When a sufficient length of piston rods have been added to the string to contact the piston rod extension which is located at the top of the sampler, screw the piston rods in a clockwise direction onto the piston rod extension. After the piston rods have been connected to the piston rod extension, continue the clockwise rotation of the piston rods for seven revolutions to unlock the piston.

Prior to sampling, secure the piston rods to the drill-rig mast or to a frame which is independent of the drill rig. Place a reference mark (use grip pliers) on the piston rod at the top of the drill rods. Advance (push) the sampler into the undisturbed soil using the drill-rig drive in the same manner as described for the thin-walled open-tube sampler. The sampler should be advanced into the undisturbed soil at a uniform, continuous rate without exceeding 75 cm (30 in.). The push should be stopped if the drill rig is lifted off the ground, as the sample could be disturbed or the sampler could be damaged. After the sampler is advanced, clamp a vise grip pliers on the piston rod at the top of the drill rod string to prevent the piston rod from sliding down. Measure and record the distance between the original reference mark and the top of the drill rods. This distance is the push length.

At the end of the drive, rotate the drill rods clockwise two rotations to shear the sample at the bottom of the sampling tube and to lock the piston. Retract the sampler into open borehole. Disconnect the piston rods from the sampler by continued rotation of the drill rods in the clockwise direction; this action allows the piston rods to be removed before the sampler is withdrawn. Remove the sampler from the borehole. During the withdrawal of the sampler from the borehole, the piston is held stationary at the top of its stroke by a split cone clamp. Extreme care must be exercised when the sampler is removed from the borehole to avoid jarring or losing the sample.

Remove the sample tube from the sampler after the vacuum breaker rod is removed. Make necessary measurements to the nearest 0.5 cm (0.01 ft), including sample lengths and any gap that may exist between the piston and the top of the sample. Record the data, seal the sample for shipment to the soils laboratory, identify and label the sample, and update the boring logs (see Chapter 13). Generally, the undisturbed soil sample will be sealed and shipped to the laboratory in the sample tube, unless the sample is extruded on site. After each sampling drive has been completed, the sampler should be disassembled and thoroughly washed, cleaned, lubricated, and reassembled before the next sampling drive.

(b) *Butters fixed-piston sampler*. The Butters sampler is a mechanically activated Hvorslev-type fixed-piston sampler. The basic operation of the Butters sampler is similar to the operation of the Hvorslev sampler. The basic differences are the Butters sampler has all right-hand threads and a simplified piston rod locking and unlocking mechanism; these features make the Butters sampler much easier to operate.

Because of the similarity of the Hvorslev and Butters samplers, details for operation of the Butters sampler are not presented herein. As is the case for any sampler, the mechanics of the Butters sampler must be thoroughly understood by the operator before it is used because the precision parts could be easily damaged by misuse or incorrect assembly. Therefore, it is suggested that the sampler be used only by or under the direction of an experienced operator.

(c) *Osterberg fixed-piston sampler*. The Osterberg sampler is a hydraulically activated fixed-piston sampler which is significantly different in design and operation from the mechanically activated Hvorslev and Butters samplers. Since the Osterberg sampler does not require piston rod extensions, it is faster and easier to assemble, operate, and disassemble than the mechanically-activated samplers. However, the sampler does contain moving parts with O-ring seals which require careful assembly and must be kept clean and lubricated for proper operation. Therefore, it is recommended that clear water should be used to advance the sampler because the sand particles suspended in the drilling mud are abrasive and can damage the O-ring seals; however, this recommendation may not always be feasible.

The sampler should be assembled with the piston flush with the bottom of the sampling tube and lowered to the bottom of a cleaned hole. Because the piston is fixed in position, the sampler can be placed firmly against the bottom of the hole. The drill rods should be securely attached to the drill rig to provide a reactionary force for pushing the sampling tube into the undisturbed soil.

To advance the sampler, fluid pressure is applied through the drill rods to the sampler pressure cylinder. Due to the pressure increase, the inner sampler head is forced downward to advance the sample tube into the undisturbed soil. When the inner sampler head has reached its full stroke (the sampling tube has penetrated its full depth into the soil), the pressure is relieved through bypass ports in the hollow piston rod. The change of pressure can be observed as a drop in the reading on a fluid pressure gauge. An air bubble and/or drilling fluid return observed at the top of the mud column indicates that the sampler has been advanced its full distance. The fluid pump should then be disengaged.

The sampling tube cannot be overpushed because the fluid pressure is automatically relieved by circulation bypass through ports in the hollow piston rod once the sample tube has advanced its full length. However, if the fluid pressure does not decrease and a return flow is not observed, this fact usually indicates that a full stroke or drive was not achieved. If a full drive cannot be completed, it is necessary to measure the actual drive once the sampler has been lifted out of the hole. This measurement should be noted on the boring logs.

After the drive has been completed, the sampler should be rotated two or three revolutions in a clockwise direction to lock the sample tube in position for withdrawal from the hole. The rotation of the sampler activates a friction clutch mechanism that allows the inner sampler head to grasp the inside of the sampler pressure cylinder. This action also shears the sample at the bottom of the sampling tube.

The sampler should be withdrawn slowly and very carefully from the borehole to avoid jarring or losing the sample. After the sampler has been withdrawn from the borehole, the sampling tube should be removed from the sampler. After the bolts or screws which are used to attach the sampling tube to the sampler head have been removed, the vacuum which was developed as a result of the sampling drive must be released before the tube can be removed from the head. The vacuum can be released by drilling a small hole through the tube just below the piston. Once the vacuum has been released, the sample tube can be removed from the sampler. Necessary data should be recorded, the sample should be sealed and identified, and the boring logs should be updated (see Chapter 13). The sampler should be disassembled, washed, cleaned, lubricated, and reassembled for the next sampling drive.

(d) *Modified Osterberg fixed-piston sampler*. The modified Osterberg fixed-piston sampler, like the Osterberg sampler, is a hydraulically activated fixed-piston sampler. It uses the same basic design and principles of operation as the conventional Osterberg sampler. All of the general procedures described for the Osterberg sampler also apply to the modified Osterberg sampler.

The major differences and improvements in the modified Osterberg sampler as compared to the conventional Osterberg sampler include a more rigid sampler which increases it applicability for sampling soils containing fine gravels, the use of aluminum sample liners with a case-hardened replaceable driving shoe, and the addition of a vent hole in the thick-walled inner sampler barrel to allow the vacuum seal to be broken for removal of the liner. During sampling operations, the undisturbed sample can be easily removed from the sampler by simply removing the driving shoe and pulling the aluminum liner out of the inner sampler barrel. Reloading of the sampler is accomplished by sliding a new liner into the inner barrel, attaching the driving shoe, and pushing the inner barrel into the pressure cylinder. Because of the similarity of the Osterberg and the modified Osterberg samplers, details for operation of the modified Osterberg sampler are not presented herein. As is the case for any sampler, however, the mechanics of the modified Osterberg sampler must be thoroughly understood by the operator before it is used, as the parts could be easily damaged by misuse or incorrect assembly. It is suggested that the sampler be used only by or under the direction of an experienced operator.

*b. Core barrel samplers*. When the material to be sampled contains gravel or is too hard to penetrate with the thin-walled push-tube sampler, double- or triple-tube core barrel samplers such as the Denison sampler or the Pitcher sampler which are described in Chapter 5 may be used. To sample, the core barrel is lowered to within a few tenths of a foot from the bottom of the borehole and circulation of the drilling fluid is begun; the circulation helps to remove cuttings that may have settled to the bottom. The core barrel is then lowered to the bottom of the hole, rotated, and forced downward at a uniform rate. The bit pressure, speed of rotation, and drilling fluid pressure must often be determined experimentally because of the variety of core barrels, drilling fluids, and variations of the soil formations which are encountered.

The speed of rotation and the rate of advance must be adjusted to ensure continuous penetration by steady cutting of the bit. The rate of penetration should not be greater than the speed at which the outer barrel is able to cut. If the bit is advanced too rapidly, it may become plugged and grind away on the core. If the bit is advanced too slowly, or intermittently, the core will be exposed to excessive erosion and torsional stresses. The rotational speed of the bit should be limited to that which will not tear or break the soil sample. Generally, 50 to 150 rpm is satisfactory for coring most soils. The Denison sampler is advanced at a speed which allows the sample to move into the sampler without disturbance. Sampler rotation, fluid pressure, downward force, and sampler configuration should vary with the type of soil being sampled.

The drilling fluid pump pressures and flow rates should be the minimum necessary to circulate the fluid freely, carry the cuttings from the hole, and stabilize the borehole walls. Too much drilling fluid pressure and too high of flow rate will erode the core, whereas too little drilling fluid pressure and too low of flow rate will plug the bit and may allow the cuttings to enter the core barrel with the core or plug the annulus between the inner and outer barrels.

Extension of the inner barrel cutting shoe beyond the outer barrel cutting teeth depends upon the soil type. The length of the extension should be the least amount which will result in a full sample that is not undercut or contaminated by drilling fluid. If the soil formation is easily eroded, the cutting shoe should be extended below the cutting teeth of the outer barrel. If the cutting shoe will not penetrate the soil, the cutting edge must be adjusted even with or slightly above the cutting teeth of the bit.

The total length of the sampling drive should always be a few inches short of the length of the sampler to ensure that the sample is not compacted in the sampler. A sampling drive of 50 cm (20 in.) plus the length of the cutting shoe is a reasonable value for the total length of drive. A core catcher should not be used unless absolutely necessary to retain the soil. If a core catcher has been used, it should be noted on the data form. After the sampling drive has been completed, the core barrel sampler should be carefully withdrawn from the borehole to avoid disturbing the sample. The drilling practices, which are suggested in paragraph 4-7, should always be followed.

*c. Hollow-stem auger sampler*. The hollow-stem auger sampler consists of a rotating outer auger barrel with cutting bits at its bottom and a stationary inner barrel with a smooth cutting shoe. The principle of operation is similar to the operation of the core barrel sampler; the inner barrel remains stationary and slides over the sample in advance of the rotating outer barrel. The outer barrel enlarges the hole above the sample. Cuttings are lifted to the surface by the auger flights on the outer barrel, which also acts as casing in the borehole. Additional sections of auger can be added as the borehole is advanced.

The auger is rotated and forced downward in one continuous motion. Proper rotation speed and downfeed pressure are required to advance the auger sampler and to clean the borehole. Excessive downfeed pressure could cause the auger to corkscrew into the ground and bind in the hole. A center pilot bit or center auger, which can be removed at any depth and replaced with the inner barrel assembly for sampling, can be used to keep the hollow stem open. If the hollow-stem auger is used as casing below the groundwater level, the center pilot bit and auger sections should be fitted with O-rings to prevent leakage. However, if the center pilot bit must be removed for any reason, the hydrostatic pressure inside the hollow-stem auger should be adjusted to the hydrostatic pressure outside the auger barrel to prevent heaving at the bottom of the barrel as the center bit is removed.

## 6-5. Preservation of Samples

Undisturbed samples must be handled and preserved in a manner to preserve stratification or structure, water content, and in situ stresses, to the extent possible. Once the sample has been removed from the borehole, it must be either sealed within the sampling tube or extruded and sealed within another suitable container prior to shipment to the laboratory for testing. In general, carbon steel tubes should not be used if the samples are to be stored in the tubes for an extended period of time because the tubes will rust or corrode and may contaminate the sample. If extended storage is required, containers made of alternative metals or wax-coated cardboard tubes should be considered. Samples for water content determination must be sealed to prevent changes of soil moisture. If glass jars are used, the gasket and the sealing edge of the container must be clean to ensure a good seal. Guidance for preservation and shipment of samples is given in Chapter 13 and in ASTM Standard D 4220-83 (ASTM 1993).

*a. Storing samples in sampling tubes*. About 5 cm (2 in.) of material must be removed from the bottom of the sampling tube to provide a space for an expandable packer, as shown in Figure 6-3, or similar device, such as prewaxed circular wooden blocks, for sealing the tube. The expandable packer consists of two metal or plastic disks which are separated by a thick rubber O-ring. Tightening the wing nut which is used to hold the disks together will squeeze and force the rubber O-ring against the wall of the sampling tube to provide a moisture-proof seal. The cup cleanout auger in Figure 6-4 can be used to remove material from the bottom of the sampling tube. It produces a plane surface on which the packer may rest. The soil which is extracted from the bottom of the sampling tube should be placed and sealed in a jar or other suitable container so that it may be used later for classification and/or water content determination.

(1) *Cohesionless soils*. Immediately after the sampler has been withdrawn from the borehole, a perforated, expandable packer, similar to the one shown in Figure 6-5, must be inserted in the bottom of the sampling tube. A sheet of filter paper or paper towel should be placed between the packer and the sample. The paper will allow excess moisture to drain from the sample without losing the cohesionless material. Drainage of water from the sample will help to prevent liquefaction and minimize the sample disturbance caused by sample handling.

After the packer has been inserted in the bottom of the tube, the tube and the sampler should be carefully removed from the drill rods as a unit and kept in an upright orientation. The lower end of the tube should be placed on a firm cushioned base, and the sampler head and piston removed from the tube. Cuttings at the top of the sample tube should be noted, measured, and removed with a cup cleanout auger; free water can be removed with a suction bulb before a perforated expandable packer and filter paper or paper towel are placed against the top of the sample.

After the tube has been sealed, it should be placed in a vertical rack to allow the free water to drain. The time required for proper drainage depends on the fines fraction of the soil. Twenty-four to forty-eight hours (hr) is usually acceptable for most soil types. Under no circumstances should the sample be permitted to dry completely, as it is impossible to trim or slice a sample of dry sand or to remove it in increments for density determinations.

Throughout the preceding operations, the sampling tube should be maintained in a vertical position from the time the sample is obtained until drainage is complete. Extreme care must be exercised to avoid disturbance of the sample by rough handling or jarring. After the sample has drained, it is ready for removal from the sampling tube for field testing or for preparation for shipment to the laboratory.

Cohesionless sands may be frozen in the sampling tube and kept in a frozen state until they are tested in the laboratory. Prior to freezing, the samples should be thoroughly drained to prevent disruption of the soil structure due to the expansion of water upon freezing. Judgment should be exercised when freezing cohesionless samples containing fines or silt or clay lenses. Not only do the silt and clay lenses expand upon freezing, the lenses also impede drainage. The water in improperly drained zones will expand upon freezing and disturb or destroy the soil structure.

(2) *Cohesive soils*. Undisturbed samples of cohesive soils are usually removed from the tube soon after the sample is obtained. However, if the sample is to be preserved in the thin-walled sampling tube, a small amount of soil should be removed from the bottom of the tube and placed in a suitable container. Cuttings at the top of the sample tube should be noted, measured, and removed with a cup cleanout auger; drilling mud can be removed with a suction bulb. The sample tube should then be sealed with a solid, expandable O-ring packer or some other suitable method, as described previously.

*b. Removing samples from sampling tubes*.

(1) *Cohesionless soils*. Measurements to determine in situ densities can be made in the field by removing the soil from the tubes in increments and determining the volume and weight of the soil for each increment. The cup cleanout auger can be used for removing the soil. With the sampling tube oriented in a vertical direction, the cup cleanout auger is inserted in the tube to the top of the soil and rotated in a clockwise direction with a slight downward pressure. After a small amount of soil has entered the auger, the soil will bridge over and stop the cutting action of the auger. The auger should not be forced further but should be withdrawn and the soil should be removed. The process should be repeated until the desired increment of the sample has been removed. A small amount of soil may adhere to the sidewalls of the sampling tube. It should be removed and included with the soil increment. The sampling tube wall scraper, as shown in Figure 6-6, consists of a beveled plate attached to a rod.

(2) *Cohesive soils*. Undisturbed samples of cohesive soils which are to be removed from the sampling tubes should be extruded immediately after the sample has been withdrawn from the borehole. A delay in removing cohesive materials from the tube allows adhesion and friction to develop between

the sample and sampling tube. The result may be greater than normal sample disturbance due to the extrusion process.

Prior to extruding the sample, the bottom end of the soil sample should be trimmed properly so that the sample extruding piston fits against a plane surface perpendicular to the axis of the sample. The sample should be extruded from the sampling tube in the same direction as it was sampled using one smooth, uniform stroke of the jack to minimize sample disturbance. The sample should be extruded onto a half-section receiving tube made from a tube of the same diameter as the sampling tube. The sample then can be examined, the classification and stratification of the sample can be noted, and the sample preserved for shipment to the laboratory. Logging time must be kept to a minimum to prevent moisture loss, slaking, etc.

The use of hydraulically activated sample jacks is the most satisfactory method for extruding soil samples from the sampling tube. Mechanical sample jacks should be used only when hydraulic pressure is not available. Pneumatically activated sample jacks are not satisfactory for extruding undisturbed samples from sampling tubes. The pressure required to overcome the frictional forces between the sample and the sampling tube is usually considerably greater than the pressure required to extrude the sample. Once the frictional forces have been overcome, the compressed air in the pneumatic cylinder ejects the sample too rapidly. Serious sample disturbance frequently occurs. Figure 6-7 shows a hydraulic sample jack operated by the hydraulic system of the drill rig. Figure 6-8 shows a manually operated mechanical sample jack.

Cohesive samples which have been extruded from the sampling tube may be placed in wax-coated cardboard tubes which are approximately 25 mm (1 in.) larger in diameter than the sample itself. A wax mixture, such as a 1:1 mixture of paraffin and microcrystalline wax, should be placed around the soil sample to minimize changes of water content and disturbance of the sample. The temperature of the wax should be less than about 10 deg C (18 deg F) above its melting point, as wax that is too hot penetrates the pores and cracks in the soil and limits the usefulness of the samples. Qualitatively, an object such as a pencil that is inserted in wax at the proper temperature for coating samples will be coated with congealed wax immediately upon withdrawal; the wax coating will not bond to the object. If the wax is too hot, it will appear clear and bond to the object.

The sample must be placed carefully into the cardboard sample tube to prevent damage to the sample. The sample should be centered in the tube to ensure a continuous coating of wax. Premolded wax base plugs, which are shaped to aid in centering the sample, eliminate the need for pouring a base of wax in the tube. After the sample has been placed in the tube and centered, a small amount of wax may be poured around the sample to soften the base to assure bond between pours. The annular space between the sample and the sampling tube should be filled and the top of the sample should be covered with wax. In general, the sample should not be wrapped with foil or plastic. However, a material which is too friable to handle may be wrapped with cheesecloth for added strength as required for handling.

## 6-6. Boring and Sampling Records

After the soil samples have been removed from the sampling apparatus, visually identified according to the procedures and methods which are presented in Appendix E of this manual, and sealed in appropriate sample containers, the sample containers should be identified and labeled and the boring logs should be updated.

All tubes and samples should be labeled immediately to ensure correct orientation and to accurately identify the sample. ENG Form 1742 and/or ENG Form 1743, as shown in Figure 13-1, should be completed and securely fastened to each sample. The information on the sample identification tag should include project title and location, boring and sample number, depth and/or elevation interval, type of sample, recovery length, trimmed sample length, sample condition, visual soil classification, date of sampling, and name of inspector. All markings should be made with waterproof, nonfading ink. Pertinent boring information and sample data, as discussed in paragraph 13-3, must be recorded in the boring log.

In addition to the aforementioned data which were placed on the sample identification tag, clear and accurate information which describes the soil profile and sample location should be documented in the boring logs. Record any information that may be forgotten or misplaced if not recorded immediately, such as observations which may aid in estimating the condition of the samples, the physical properties of the in situ soil, special drilling problems, weather conditions, and members of the field party. Figure 6-9 presents an example of a boring log of an undisturbed sample boring.

## 6-7. Shipment of Samples

The most satisfactory method of transporting soil samples is in a vehicle that can be loaded at the exploration site and driven directly to the testing laboratory. This method helps to minimize sample handling and allows the responsibility of the samples to be delegated to one person. Samples shipped by commercial transportation companies require special packing or crating, special markings, and instructions to ensure careful handling and minimum exposure to excessive heat, cold, or moisture. In general, jar samples from the bottom of the tube samples can usually be packaged in containers furnished by the manufacturer, although special cartons may be required if considerable handling is anticipated. Undisturbed sample tubes should be packed in an upright orientation in prefabricated shipping containers or in moist sawdust or similar packing materials to reduce the disturbance due to handling and shipping. For certain cases, special packing and shipping considerations may be required. Regardless of the mode of transportation, the soil samples should be protected from temperature extremes and exposure to moisture. If transportation requires considerable handling, the samples should be placed in wooden boxes. Additional guidance is presented in Chapter 13 and in ASTM D 4220-83, “Preserving and Transporting Soil Samples” (ASTM 1993).

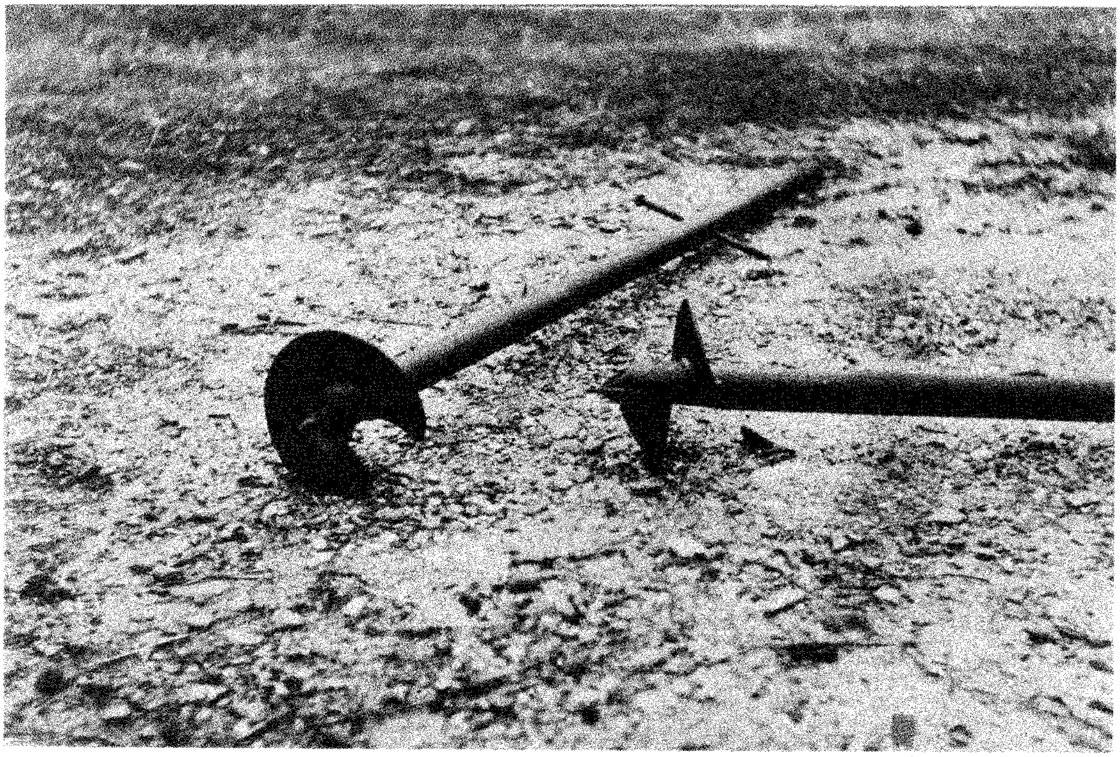

Figure 6-1. Photograph of a screw-type earth anchors

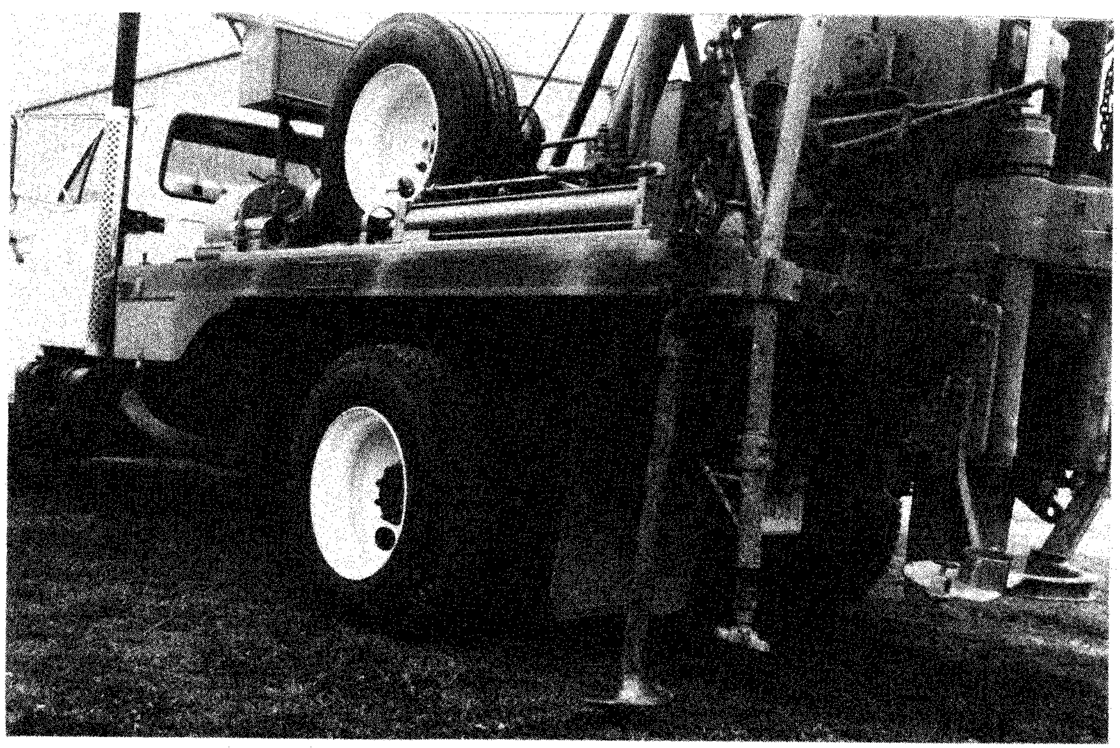

Figure 6-2. Photograph of screw-type earth anchors fastened to the drill rig with load binders to anchor the rig

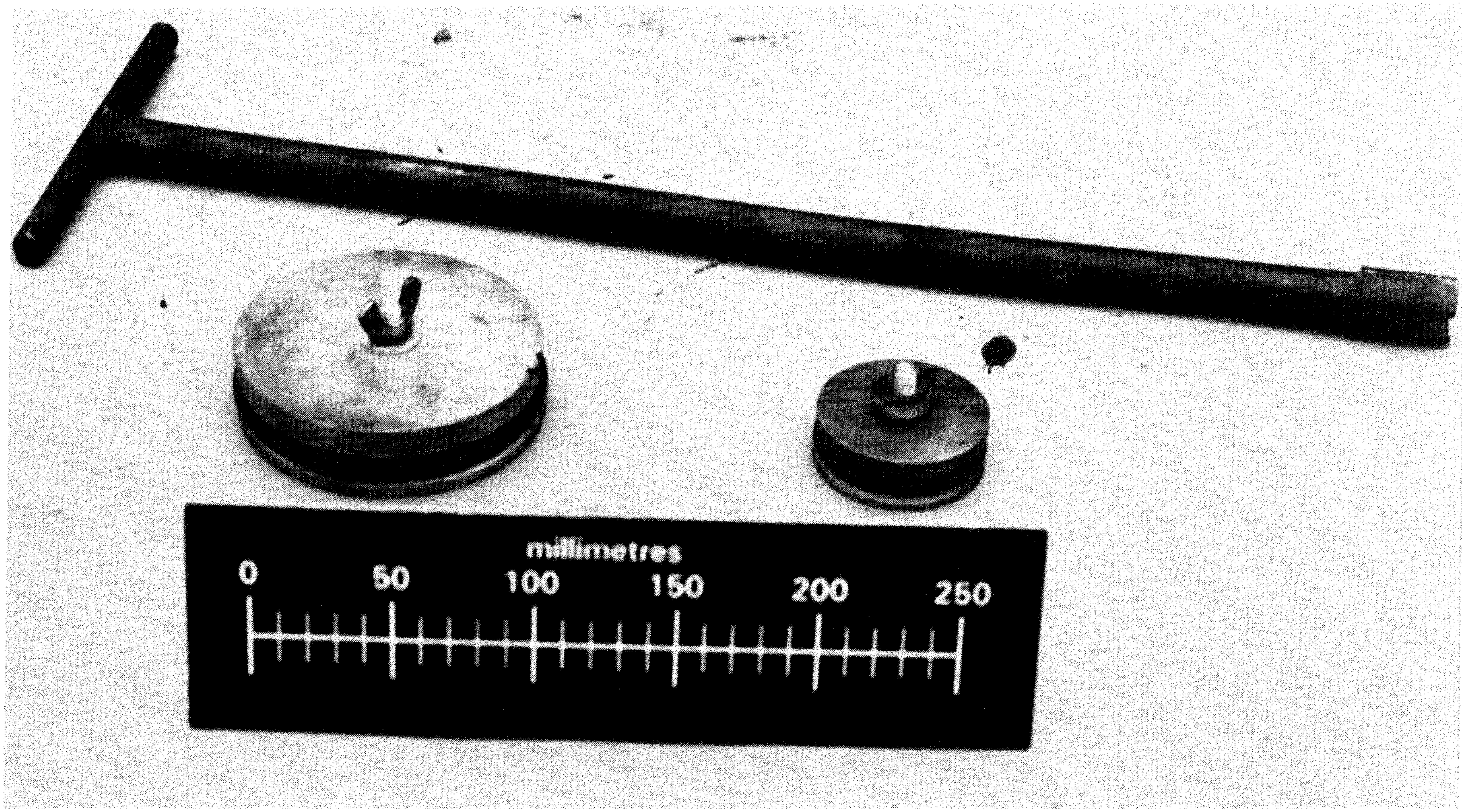


**Figure 6-3. Photograph of an expandable packer**

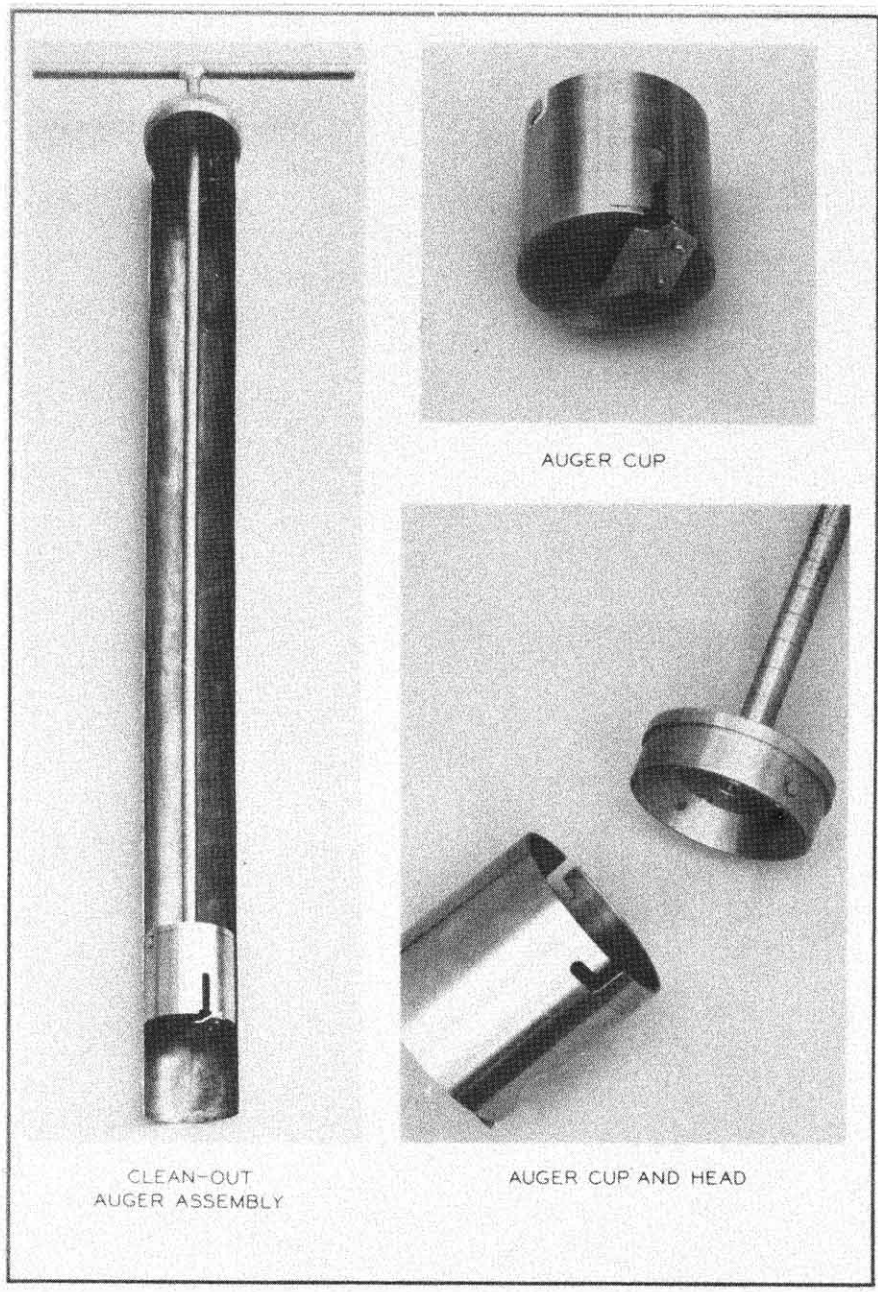


**Figure 6-4. Photograph of a cup cleanout auger which is used to remove material from the bottom of the sampling tube**

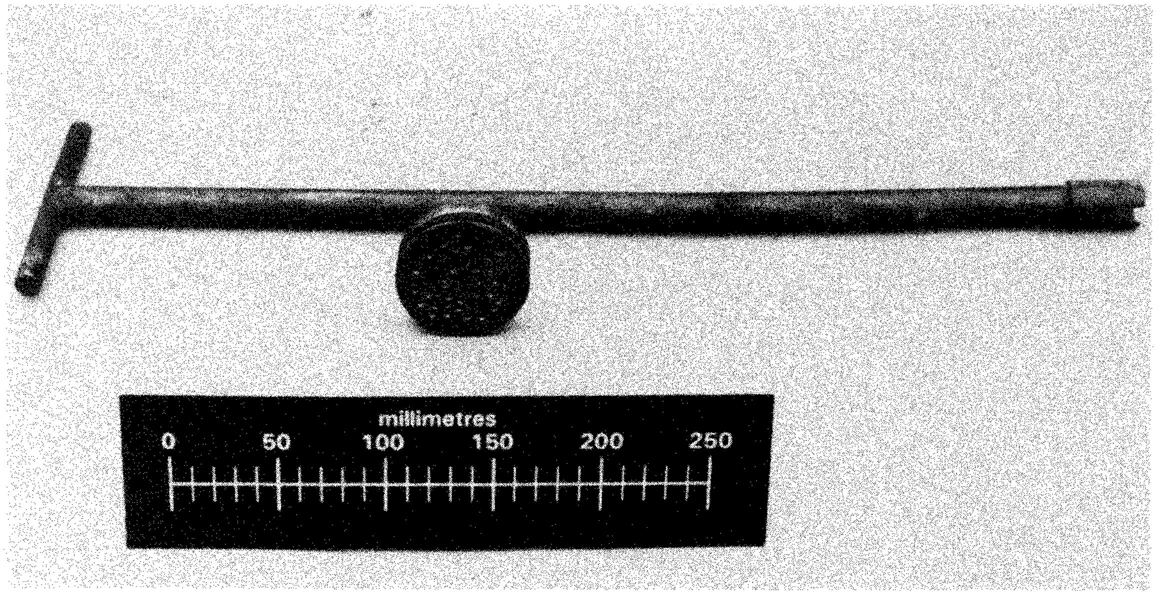


**Figure 6-5. Photograph of a perforated, expandable packer**

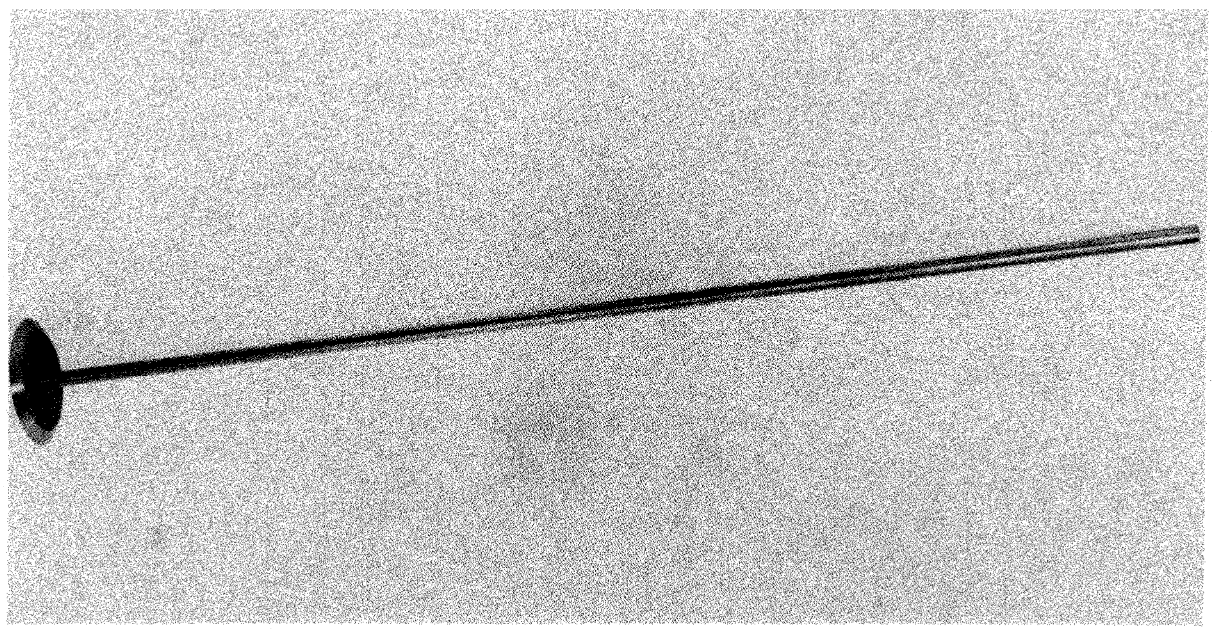

**Figure 6-6. Photograph of a sampling tube wall scraper**

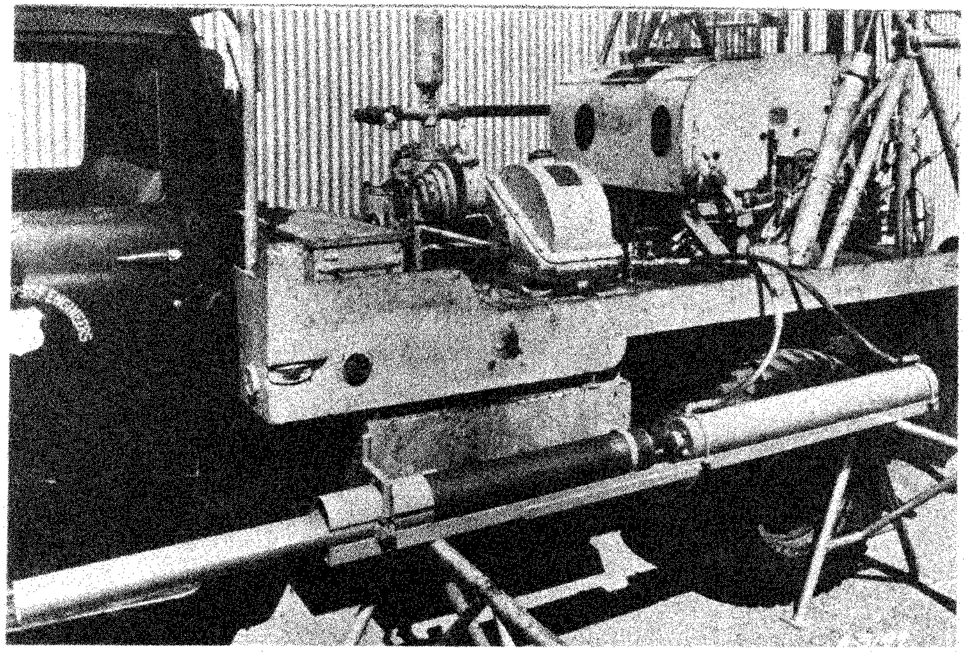

Figure 6-7. Photograph of a hydraulic sample jack which is operated by the hydraulic system of the drill rig

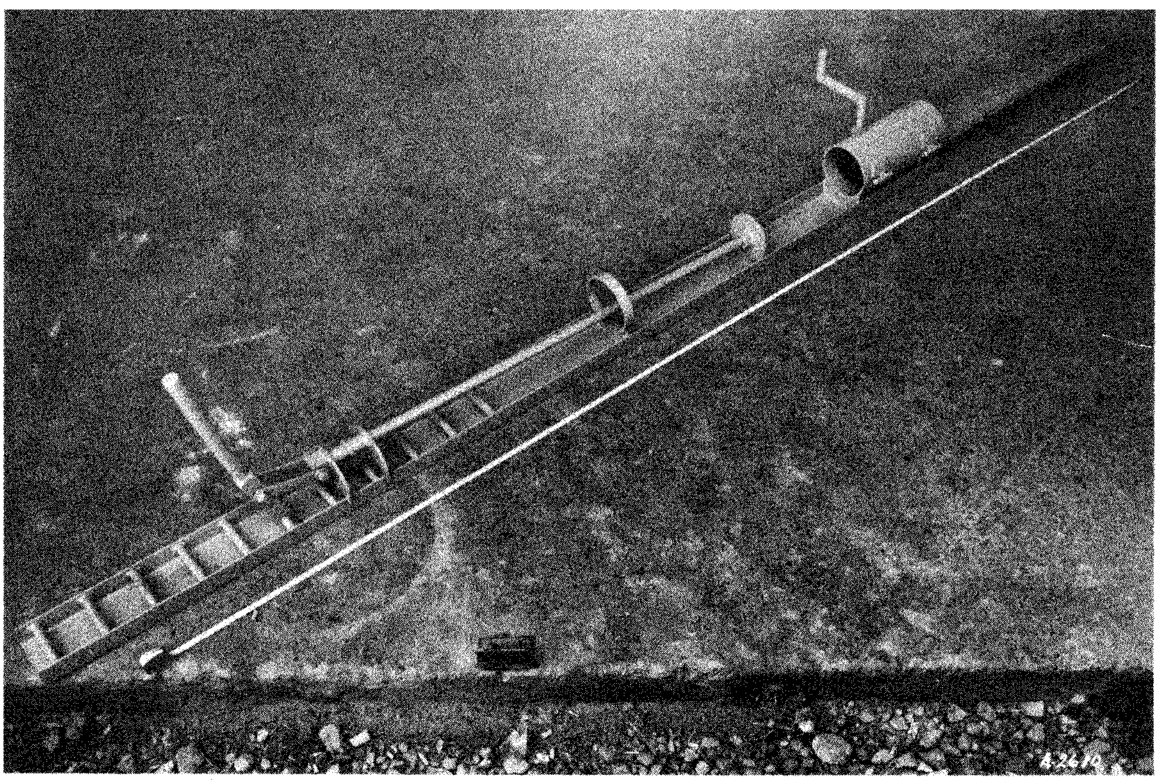

Figure 6-8. Photograph of a manually operated mechanical sample jack

# BORING LOG
## FIELD DATA

Project Morville Revetment Slide Location Range 2, Riverside 400' Date 16 July 1971
Drill Rig W-4048 Inspector Elliot Operator Brown Surface elev 58.0 ft. MSL
Levee District Concordia Job No. 7063 Boring No. MR-1

| SAMPLE NUMBER | DATE TAKEN | STRATUM | | DRIVE | | SAMPLE | | TYPE OF SAMPLER | CONTAINER | HYDRAULIC PRESSURE OR BLOWS | CLASSIFICATION AND REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | FROM | TO | FROM | TO | FROM | TO | | | | |
| — | 16 July | 0.0 | 11.5 | 0.0 | 12.0 | — | — | 6" Fishtail | — | — | Brown silty clay, stiff CL |
| 1 | 16 July | 11.5 | | 12.0 | 12.5 | 12.0 | 13.2 | 5" Shelby Tube | Tube | 20 | Gray clay, med. CH |
| 1A | | | | 12.5 | 13.0 | 13.2 | 13.3 | " | Jar | 80 | |
| | | | | 13.0 | 13.5 | | | | | 100 | (Drive, 2.50'; Sample, 2.50'; |
| 2 | | | | 13.5 | 14.0 | 13.3 | 14.4 | " | Tube | 160 | Gap Between Sample |
| 2A | | | | 14.0 | 14.5 | 14.4 | 14.5 | " | Jar | 180 | & Piston, 0.00') |
| — | | | 16.2 | 14.5 | 16.5 | — | — | 6" Fishtail | — | — | Gray clay, med. CH |
| 3 | 16 July | 16.2 | | 16.5 | 17.0 | 16.5 | 18.9 | 3" Shelby Tube | Tube 26 | 100 | Gray sand, fine SP |
| | | | | 17.0 | 17.5 | | | | | 160 | (Drive, 2.48'; Sample, 2.42'; |
| | | | | 17.5 | 18.0 | | | | | 200 | Gap 0.06') |
| | | | | 18.0 | 18.5 | | | | | 280 | (Mud Wt. 70.0 Lb/Cu Ft) |
| | | | | 18.5 | 19.0 | | | | | 320 | |
| — | 16 July | | | 19.0 | 22.0 | — | — | 3½" Fishtail | — | — | Gray sand, fine SP |
| | | | | | | | | | | | (Mud Wt. 71.0 Lb/Cu Ft) |

WES FORM NO. 819
REV FEB 1971

Sheet 1 of 4 Sheets

**Figure 6-9. An example of a boring log of an undisturbed sample boring**